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Configurations of Plague: Spatial Diagrams in Early Epidemiology.

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Abstract: Diagrams are found at the heart of the modern history of epidemiology. They have been used to visualize specific spatio-temporal characteristics of epidemics, to draw out models of ecology as well as to conceptualize vectors with a scope ranging from microscopic pathogenic pathways to global transmission routes. Epidemiologists have long worked with spatial diagrams to visualize concepts of epidemics as arrangements of biological, environmental, historical as well as social factors. These diagrams observe, articulate and analyze an epidemic as configuration. Often, they provide a representation of the networks of relationships implied by an epidemic, rather than to offer conclusions about origin and causation. This article will look at two spatial diagrams of plague across a period in which epidemiologist's persistence to their own diagrammatic way of reasoning stood in stark contrast to arguments provided about plague in the rising field of bacteriology and experimental medicine. The historical genealogy of epidemiologist's workings with diagrams presented in this article challenges perceptions of epidemic diagrams as mere arguments of causality and blueprints for prevention. Instead the images of plague serve as examples to emphasize diagrammatic notions of uncertainty, crisis and invisibility.

Keywords: epidemiology, bubonic plague, history of science, spatial diagram, diagrammatic, configuration

Word Count: 8241+750 (3 figures)=8991

Introduction

Spatial diagrams have long been essential instruments in visualizing epidemics. They configure epidemics on maps, enhance the recognition of epidemic processes spanning time and space while integrating an indefinite series of ecological, environmental, biological, social and cultural aspects. They draw together structures, concepts, systems, theories and ideas, brought into significant relation through an epidemic. They structure the dynamic nature of an outbreak over time and serve the purpose of situating epidemics on the ground, when they attach the topography of a series of disease cases to the geographical coordinates of a place. In this article I will argue that epidemiology's spatial diagrams come closest to *represent* the epidemic itself. In the history of epidemiology as science, the epidemic has always been a rather peculiar object. Neither a natural object like bacteriology's pathogens, nor a social entity like demography's populations, the epidemic maintains a tension between observed event and conceptual framework; a tension, best preserved and presented in the spatial diagram.

The term spatial diagram, as used throughout this article, is not coincidently borrowed from architecture and landscape design (Vidler 2000). The principal purpose of such diagrams is the location and integration of a conceptual entity, a design or structure, within a given landscape or environment. To this end, spatial diagrams offer a clear iconographic distinction between the visualization of the given context, often found in a common map, and the representation of an envisioned structure as an abstract, or diagrammatic entity. The spatial visualization of an epidemic involves a comparable combination of a map of a given environmental context with references to the spatial and temporal pattern of a series of cases of a disease. Within the terms of epidemiological reasoning, the spatial diagram is perhaps best understood to be a hybrid between maps and functional diagrams. While both the map as well as topological diagrams of e.g. the hierarchy of cases have been employed widely in epidemiology and public health, it is in the spatial diagram, where the abstract entity of an epidemic is be captured most reliably and consistently (Koch 2011).

In recent social science literature, maps and diagrams of epidemic events have received a range of attention. Many perceive the epidemic map and diagram as instruments of social control, as visualizations of power structures, blueprints of containment strategies or as strategic investments in the normalization of societies and pathological behavior (Monmonier 2010). Maps and diagrams of epidemics can be seen as simulations of possible worlds, as models for worlds of social relations; "animated social theories" structured by contagious and infectious phenomena (Opitz 2017, 394). Or, with Carlo Carduff, maps and diagrams can be addressed as cybernetic ways of knowing the epidemic, where reductionism and incompleteness express immediacy and urgency, without aiming for comprehensive accounts and stabilized sets of information (Caduff 2015). On the other hand, for Christos Lynteris, the zoonotic diagram in particular "embodies and reproduces fundamental principles of interspecies relations," which informs biopolitical human-animal relationships (Lynteris 2017, 464).

These authors have analyzed epidemic diagrams to grasp the effects and the technologies of power imbued into these graphic devices and visual modes of reasoning. Here, I focus on a different question: I step back from an analysis of the political implications and power dynamics of epidemic diagrams and maps, and ask instead about the relationship between what we consider to be an epidemic, and how this precarious object of knowledge is captured and demarcated in visual representations. This inquiry is methodologically located in a history of science to unpack the hardened traditions of visualizing epidemics that structure epidemiological representations until today. Here, I take two exemplary historical cases of spatial diagrams of the same disease from a crucial period of disciplinary boundary-setting in epidemiology. Both cases convey a clear picture of an epidemiological diagrammatic of configuration which maintained epistemological distance to questions of origin or causation.

The historian of medicine Charles Rosenberg has offered a now-famous answer to the question, what is an epidemic? Prompted by the developing AIDS crisis, he proposed in the early 1990s that we grasp epidemics as events, rather than as trends. He suggested a "dramatic'" framing for understanding the spatial and temporal development of an outbreak as a series of choreographic events. Moreover, Rosenberg identified two conceptual frameworks through which people have explained epidemics and made sense of the epidemic event in the past. The first, *configuration*, emphasized a systems view, in which epidemics were explained as "a unique configuration of circumstances" of categorical equal significance (Rosenberg 1992: 295). Communal and social health was seen as a balanced and integrated relationship between humankind and environmental constituents, in which epidemics appeared not only as the consequence, but also as the origin of disturbance, crisis and catastrophe. Rosenberg's second framework, *contamination,* focused on a different view, which prioritised particular and identifiable causes for an epidemic event. Where configuration implies holistic concepts, the contamination perspective suggested a disordering element, a *causa vera*, and implied a reductionist and mono-causal way of thinking. As

Rosenberg emphasises, both of these themes have existed since antiquity in epidemiological reasoning, but it is particularly in the late-nineteenth century, with the emergence of bacteriological science, when we see a proliferation of these themes into polemical dichotomies. Already seeded with conflicts between contagionists and anti-contagionists throughout the nineteenth century, the theme of configuration became overwhelmingly identified with the sanitary beginnings of epidemiology. The bacteriological laboratory, on the other hand, introduced bacteria as a superior principle of contamination. But contrary to the stock-narrative of the bacteriological revolution, the principle of contamination never achieved autarchy in the explanation of epidemics, and the laboratory was kept at a critical distance to the epistemology of epidemiology.

As Olga Amsterdamska has argued, epidemiology long struggled to constitute itself as a discipline and many of the doctors and health officers which indeed were involved in the observation, analysis and classification of epidemic events would hardly call themselves epidemiologists far into the twentieth century. But during this period of disciplinary demarcation and boundary work, epidemiology did continue to preserve its commitment to systems, ideas of equilibrium and balance throughout the late-nineteenth and early-twentieth century (Amsterdamska 2005). Epidemiologists carried out boundary work to safeguard their own inductive modes of reasoning against the reductionist simplifications of the equation, that if one microbe leads to one disease, a number of it would lead to an epidemic. Instead the turn of the nineteenth century was characterized by a distinctive proliferation of theories and concepts, which integrated bacteriology seamlessly into other modes of epidemiological reasoning, including history, sociology, demography and early versions of ecology. Amsterdamska argues that "epidemiologists reacted to the advent of the germ theory of disease neither with hostility and rejection nor with the belief that the new theory implied a subordination of their own findings to those of the bacteriological laboratory" (Amsterdamska 2004: 486). Andrew Mendelsohn argues in a similar direction, when he channels epidemiologists' persistence in defining their field "in terms wider than the microbic incitants." (Flexner, quoted in Mendelsohn 1998: 306) The traditional basis of epidemiology – history, environment, statistics - never disappeared in the face of bacteriological science, but rather became a "countertrend." Contrary to a popular picture, epidemiology did not require bacteriological expertise about pathogens, nor did bacteriology or germ theory offer a missing piece to epidemiological puzzles. Instead, epidemiology had already developed a distinctive and robust set of practices, methods and ways of reasoning to observe, articulate and analyse the configuration of epidemic events.

In this article I argue that spatial diagrams were substantial tools for the boundary work undertaken by epidemiologists to safeguard notions of complexity, to preserve system-thinking and – most importantly – to study epidemic phenomena without adhering to the identification of contaminations suggested by bacteriological investigations. In other words, the spatial diagram furthered the tradition of inductive reasoning committed to open-ended observation and association, which was akin to epidemiology and stood in strong contrast to the deductive methods of the laboratory (Parascandola 1998; Bauer 2013). The history of spatial diagrams in epidemiology has the capacity to challenge common misunderstandings, which prevail until today when reading and interpreting epidemiological maps and spatial diagrams as prove of causality and origin.

According to Christina Ljundberg, maps as well as spatial diagrams share the capacity to "structure domains into networks of relationships," to achieve both likeness and hybridity. "That hybridity is what makes the map an efficient tool not only for exploring unknown territories but also for discovering new relationships that no verbal description could reveal" (Ljungberg 2016: 142). Since John B. Harley's critical commentary on cartography, we have clearly moved beyond a perception of maps as reproductions of an objective image of the epidemic's reality. But Harley also reminds us that we still need to consider the map's epistemological and cultural investment in the production of objects of research which affect values and politics around the issues drawn up in geographic visualizations (Harley 1992, 4). In his reading of the disease map, Koch picks up on this perspective and pushes a step further: to him the disease map is inherently an instrument from the epidemiologist's workbench, implicated in ongoing research questions, rather than an instrument of representation or demonstration. Disease maps belong to a sophisticated "method of assemblage within which ideas are constituted and then argued about specific experiences" (Koch 2011: 13).

The spatial diagram of an epidemic is therefore a conjunction of analytic presentation and experimental presentation in visual exposition, and Koch suggests that we see disease maps as experimental systems. With reference to Hans-Joerg Rheinberger it is first an assemblage of known aspects, secured facts and well-established understandings (of environment, climate, hygienic status, population-density, cultural customs, built structures as well as characteristics of a disease, virulence of a bacteria and any other factor deemed relevant) which then goes on to emphasize those aspects that are unknown, unusual, and which seek further exploration and explanation (Rheinberger 1999).

The history of plague is uniquely qualified to demonstrate the capacity of spatial diagrams as ways to emphasize the configuration of an epidemic event over principles of contamination. The beginning of the third plague pandemic coincided with the bacteriological identification of its agent, later known to be *Yersinia pestis*, but plague and its medieval heritage had long been a favorite object to epidemiologists (Echenberg 2007; Lynteris 2016). The re-occurrence of plague in the late nineteenth century as bacteriological science enjoyed outstanding popularity, indeed offered a pathway, in which the epidemic seemed to have become an object of the laboratory, and, as Andrew Cunningham has suggested, an infectious disease seen almost exclusively through the lens of contamination (Cunningham 1992). But, as I argue here, despite the microbe's stabilized ontology, epidemiologists continued to invest in and strengthened their approaches to studying outbreaks as complex configurations and maintained their professional indifference to arguments of contamination, causality and origin.

The two cases discussed here inhabit distinct positions in the historical arch of the third plague pandemic (1894-1952). The first diagram was produced a few years ahead of the pandemic, covering a small outbreak in the Russian village of Vetlianka in 1878. The second was produced in 1899 in the Portuguese city of Porto as the pandemic reached European shores. The spatial diagrams produced for both outbreaks allow us to unearth a series of unique epidemiological perspectives on the disease, which emphasized a view of plague as a superimposition of historical narratives, environmental descriptions and disease topographies; a view which stressed uncertainty and resisted the premature attribution of causality and responsibility.

The examples furthermore enhance a historical sense of an epidemiological practice that was not yet subsumed by biostatistics and mathematical proofing but consisted in the assemblage and open-ended superimposition of a variety of fields of knowledge. In 1878 Vetlianka, we see diagrammatical reasoning about plague before bacteriological explanations were readily available. But plague's arrival on Europe's shores in the second case in 1899 demonstrates how epidemiology's diagrammatic reasoning persisted despite the availability of mono-causal frameworks. Both cases serve to excavate a forgotten practice of epidemiological reasoning: that epidemiologists working with and on diagrams assumed a capacity of radical epistemological indeterminacy. Almost any perspective, viewpoint, theory and concept could be considered and arranged into the networks of relationships, the models of configuration and the diagrams of epidemics that they were observing and drawing together.

Plague in 1878 Vetlianka –A House and Family Epidemic

The map of the 1878 plague outbreak in the Russian fishing village of Vetlianka on the banks of the Volga provides us with a remarkable diagram (Figure 1). The iconic references appear opaque, and its conceptual propositions require as much explanation as do the circumstances of the diagram's production. The aesthetic qualities of the picture mimic the isolated and outstanding position of the outbreak in Vetlianka at the time. It was the first severe epidemic of plague on the European continent in the nineteenth century, which had considerable geopolitical consequences for the hygienic reputation of the Russian Empire and attracted attention from newspapers across the English, French and German-speaking world (Heilbronner 1962). Plague was considered at the time to be contained to the Far East, India and North Africa and believed to be unlikely to ever appear in modern, hygienic Europe again. With Vetlianka bearing evidence to the contrary, the commission's members all wrote reports, drew maps and plotted graphs and diagrams to understand the precise conditions under which the epidemic had defied the advancements of European sanitation. Crucially, they wanted to know whether if it could progress further West.

On the Volga, the outbreak was understood to be the result of a series of smaller cases spanning the second half of the nineteenth century in the wider region of Astrakhan. Isolated cases tended to be attributed by local physicians to soldiers returning from China. The outbreak in the small and isolated fishing village of Vetlianka, 200 miles north of Astrakhan, probably begun in mid-October 1878, but it took until December for its arrival to be publically announced. Russian authorities immediately sent doctors to investigate the circumstances of the surprising outbreak. But, as news travelled, and out of growing concern for the hygienic reputation of the Russian Empire, an international commission from eleven European countries was invited to investigate the occurrence (Pirogovskaya 2014: 139). The commission arrived in December 1878, only to discover that most Russian physicians had already succumbed to plague, although the outbreak itself seemed to have slowed down.

Historically, the outbreak occurred at a pivotal moment. With early bacteriology beginning to find footing in the German and French centers of medicine, and with ongoing controversies regarding contagious and sanitary concepts of disease transmission, Vetlianka offered a chance for systematic observation of plague *in situ*, and for the precise definition of its epidemiological characteristics. But this should not be mistaken for an interest in the bacteriological identification of plague's microbe. Rather, the commission's members were doctors and health officers who cared little for bacteriology, and rather sought to define the precise configuration of the local conditions in the fishing village, which had turned individual cases – that had occurred before - into clusters, heaps and series. Their interest was to capture the climatic and the hygienic conditions of the local environment as well as the susceptibility of the population, their living conditions and in particular the 'pestilential' Watakas, were the villagers cured fish (Lynteris 2016, 47). While the principle of a contagion was acknowledged by the commission's delegates, at the time of the Vetlianka outbreak it played only a minor conceptual role. A microbe, which might have transmitted plague as much as the principle of contagion itself remained under-theorized in the proceedings of the commission's members as it was widely ignored in early Russian epidemiology (Hutchinson 1985; Mikhel 2018).

Russian and western European newspapers hurried to attribute the outbreak of Vetlianka to the catastrophic hygienic circumstances in the Astrakhan region. Russian physicians blamed social deprivation and growing poverty, as well as the unhygienic local fishing industry, for having introduced conditions ripe for plague to lead to an outbreak (Pirogovskaya 2014). One newspaper quoted a river-boat captain who described Vetlianka as a "malodourous place," where passengers would cover their noses when passing by. Some papers went so far as to suggest that plague was not an import at all, but that the living conditions of the poor in Vetlianka had bred plague into existence (Pirogovskaya 2014: 150).

The reports, published by Russian, German, French and English members of the commission, painted a different picture to the press. All reports follow a characteristic structure of systematic epidemiological observations in the late-nineteenth century (see e.g. Hamilton 1875; Hirsch and Sommerbrodt 1880; Zuber 1880). Extensive historical narratives of the ancient and more recent origin of plague were significant, as were the climatic conditions of the Volga Valley. The professional occupations of plague victims - most were fisherman - was considered with the same rigor as the relationship of settlements to their surrounding landscape, commonly referred to as "environs" (Radcliffe 1881: 3). What occasionally reads as pedantic and detailed accounts of seemingly disconnected elements and random aspects of an unusually widely framed historical and geographical context, constitutes the driving principles of epidemiological reasoning at the time: analyzing the history, the environment and the population (Mendelsohn 1998).

Perhaps surprisingly, the commission members seemed rather unconcerned about an opposition between contagion and individual constitution, sanitary states or miasmatic influences. Rather, their writing and drawings suggests a pragmatic approach, and an explicit interest in the configuration of the networks of relationships the epidemic had made visible. The German epidemiologist August Hirsch took the isolated occurrence of the outbreak, which had caused no more than a few individual cases in neighboring villages, to be indicative of Vetlianka presenting a rare opportunity to study those circumstances that allow plague to thrive. The "detailed investigation of the local circumstances were essential," Hirsch argued, "as this plague appears to be an isolated epidemic, which mirrored in its appearance the properties [*eigenthuemlich*] of the local conditions" (Hirsch and Sommerbrodt 1880: 5). Hirsch then went on to discuss in detail the origin of this outbreak, which he assumed to be found in the Turkish Russian war. He assumed that returning Cossack soldiers, who comprised almost half of the population in the region, might have brought the disease with them. But he also considered the topography of the landscape, the humid climate and the geology of the region, before he engaged with the hygienic circumstances and their connection to cultural habits of the Cossacks. Finally, Hirsch provided an overview of the history of other epidemics, such as malaria, in the same region, before turning to the outbreak itself. He remarked that plague in Vetlianka followed a unique pattern: cases seemed to have been confined strictly to families and their homes. Indeed, for both the first and second wave of the outbreak, almost all cases could be shown to have occurred along kinship lines. This pattern, he argued, suggested that the common belief that hygienic circumstances drove the epidemic was in need of urgent revision.

The English report, penned by J. Netten Radcliffe, opened an equally wide framework and considered the historical, geographical and climatic influences before turning to the structure of the local population to capture the "social conditions" of plague victims. After lengthy considerations of the geography, accompanied by maps, Radcliffe also gives much detail over to description of the impoverished fishing village, the wooden, makeshift structures of the dwellings, the poor sanitary state of the streets as well as its leaking cemetery. He then relied on written statements by Russian doctors who had witnessed the outbreak in December, to discuss the different waves and phases with which plague had presented itself. He, like Hirsch, focused on the remarkable fact that almost the entirety of cases had been confined to families and seemed to have spread among close relatives: “The outbreak, indeed, consisted of a series of *houses* and *family epidemics*” (Radcliffe 1881: 15 [emphasis in original]). Not only direct relatives were affected by these “family epidemics”, but also “persons brought into most familiar communication with the family.” As an example, Radcliffe points to the four Russian doctors who had been sent to investigate the epidemic. All but one of them had succumbed to plague as well as the entirety of the sanitary staff - the “feldshers” in the village - after they had visited infected houses.

G. N. Minkh, a professor of pathological anatomy at the University of Kiev, did not join the international commission, but instead went to Vetlianka on his own initiative, eager to report on the precise shape of the plague outbreak. A protagonist of experimental medicine influenced by Rudolf Virchow, Minkh spent four months in the region to conduct his research on “plague in Russia” (Minkh 1898). His report, published after his death in 1898 [1896], was written with two principal goals: first, he conducted a survey of the historical geography of plague to demonstrate that the disease spreading out of the region was highly unlikely. A series of maps of the region accompanied the report, visualizing the geopolitical significance and the historical trajectory of cases along the Caspian Sea. Second, he agreed in principal with the prominent members of the commission, and considered the local conditions of Vetlianka to be of special interest as they seemed to have allowed an epidemic to take hold that otherwise would not have settled in Europe. Understanding and mapping the conditions under which plague flourished here - and nowhere else - would thus allow for a generalized epidemiological picture of plague to be produced.

FIGURE 1 HERE

As he turned to the outbreak itself, Minkh focused on the two distinct periods of the epidemic. The first seemed to have developed slowly, was marked by classic signs of bubonic plague and had only a moderate mortality rate. The second period was characterized by many pneumonic cases, a much-increased mortality as well as a far quicker death in most cases. Not only did both periods follow family lines, as pointed out by other authors, but the second period also began in the particularly wealthy family of Osip Belov. For Minkh, this was reason enough to abandon any investigation into the hygienic state of dwelling or the hygienic living conditions of plague victims; rather, he developed a different research question which followed the kinship structure of the epidemic.

Yet the concept of a “family epidemic”, as put forward by Radcliffe, did not make for a sufficient explanation of the observable pattern in Vetlianka. Rather Minkh asked if the epidemic indeed followed a genealogy, and why some members of the same family who also had been in touch with sick family members were not affected. Furthermore, if the epidemic was to be understood in terms of proximity and contagion alone, why were dwellings next to infected houses often spared? His diagram of the topography of the outbreak of plague in Vetlianka followed these two questions (Figure 1). Minkh used a geographic map of the village, which indicated the river in the North and the structure of dwellings throughout the town. To provide a representation of the social space, he indicated the positions of churches, the doctor’s and feldshers’ homes, as well as the cemetery. He then developed a unique system of icons, arrows and visual statistics to visualise the temporal and spatial characteristics of the epidemic. All remaining iconographic references were dedicated to the visualisation of the spatial structure of morbidity and mortality, and the assumed spread of plague.

Houses marked as red, orange or yellow were affected by the first, mild outbreak. Red houses were those where more than one person had died. In orange, at least one case had been fatal. Yellow were all the remaining dwellings with cases of plague that recovered. Red arrows indicated the direction of transmission of the first period of the disease, where Minkh identified the transmission from house # 10 to house # 58 as the beginning of the second period. The structure of the second wave is split in two principal clusters. Three shades of blue indicate all houses belonging to the Belov family, with the darkest blue pointing to the total extinction of households, while the second and third shade signified a larger or a smaller mortality. The three shades of grey were then used to indicate the houses of other families, not directly related to the Belovs with a similar codification of fatalities.

Minkh argued that the diagram visualized a more complicated pattern than just an epidemic of family houses or of bloodlines. Rather, he could show that the two periods of the epidemic appeared in different spatial configurations. The first seemed to have largely been contained in the East of the village, with only isolated cases breaking out in other areas. The second, more violent period had also begun within a family, the Belovs, but had caused cases and pockets of outbreaks throughout the village. Most importantly this map shows that this outbreak was neither structured solely by family bloodlines, nor did it follow a clear pattern of spatial distribution. Through his complex visualization, Minkh was able to show that the characteristics of plague in Vetlianka needed to be seen as both a plague of "family epidemics" and as a disease of contagious nature, distributed beyond the families on the basis of contact and connections that were not explicable in terms of dwelling conditions, environmental aspects, or animal vectors.

In Vetlianka, the spatial diagram delivered a portrait of the epidemic's configuration in which two common perceptions of plague were drawn together to let a different network of relations emerge. Minkh's visualization presented plague as an epidemic of the village population that appeared to strike in two highly selective ways. Both were traceable through family lines as well as through proximity. His spatial diagram brought together concepts of lineage with questions about space and the immediate urban environment. His epidemic configuration thus resisted both a simple hygienic argument, such as carried by many newspapers at the time, and arguments promoted by the British report that considered this to be an epidemic of families and houses. Rather, his diagram insisted on the complexity of the spatial and temporal coordinates of the outbreak. Instead of attributing a cause, it integrated and sustained uncertainty in its accurate representation of the configuration of the plague epidemic, which in turn appeared as a system of interlocking factors and multiple influences.

Plague in 1899 Porto: Standardizing the Pattern of the Plague.

Three decades later, the arrival of plague in the South of Europe offers a good case for comparison. On first sight, much of the epidemiological analysis undertaken in Porto resembles the endeavors of the commission in Vetlianka. An international commission was send to the Portuguese city to investigate the circumstances under which the epidemic had managed to establish a focus in a European port. And similarly to Vetlianka, interpretations of causality were overwhelmingly focused on urban sanitary conditions. Different to Minkh's sophisticated visualization of an epidemic topography, the maps of plague in Porto illuminate another way that epidemiologists worked with spatial diagrams. Instead of inventing an innovative configuration of the epidemic, the Pasteurian Albert Calmette utilized the spatial diagram to combine different registers of observation in order to visualize and standardize, what he considered to be a characteristic and universal picture of a plague outbreak.

The epidemic of Porto happened in a very different historical and geographical context than the one in Vetlianka. The geopolitical landscape of Europe had undergone drastic changes and plague had in the meantime become a global pandemic, believed to have originated in 1894 in Hong Kong. In the same year, the Japanese bacteriologists Shibasaburo Kitasato and the Pasteurian Alexandre Yersin had identified the bacterial agent responsible for plague. Yet until the end of the nineteenth century, most European as well as American public health authorities were convinced that plague bacteria could not survive in the sanitary environment of European and American cities. Following the Porto outbreak in July 1899, a chain of plague outbreaks took place in San Francisco, Sydney, and Buenos Aires in the same year, provoking conceptual reconsideration of what had been considered favorable conditions for plague to thrive.

The first case in Porto appeared in June 1899 when a Galician stevedore died after unloading a shipment of unknown origin at the local port. In a matter of days, many of his roommates, some of whom had sat in vigil for their friend, also died and so did five women who worked and lived in neighboring houses (Echenberg 2007: 107). Ricardo Jorge, the local chief medical officer, was informed in July of the cluster of unusual cases, and after weeks of laboratory testing, he confirmed the presence of the plague bacillus in the corpses. Two months later, after Jorge's diagnosis had been confirmed, Camara Pestana from the Lisbon Royal Institute of Bacteriology declared a plague emergency. The outbreak further increased over the following months and gradually declined as winter set in. The final tally reported 322 cases of plague with 115 fatalities.[1]

Within a matter of weeks, the outbreak attracted doctors with the instruction to conduct epidemiological analysis from Spain, Germany, England, Sweden, Norway, Italy, the United States and Russia. Most arrived just before a sanitary cordon was erected around the entire city on August 24, lasting until December 22 (Almeida 2013: 9). While almost all foreign doctors agreed that the quarantine was relatively useless and probably causing more harm to the local population than plague itself, their focus was directed to an entirely different aspect of the epidemic. The French delegation, composed of Drs Albert Calmette and Alexandre Salimbeni, arrived from Paris with an anti-plague serum that promised effective immunization against the disease.[2] But Jorge among others remained skeptical about the safety of the new serum and claimed that the success of its application to curb the epidemic was dubious. Rather, he suggested to organize the removal of the poorest populations from a particular form of habitation that had come to characterize the deprived part of the city around the port (Jorge 1899: 12).

The ‘ilhas’ or ‘islands’ were backyards on long and narrow plots in which only the front was occupied by traditional middle class buildings. The remainder of the plot, accessibly only through a narrow underpass from the street, was crowded with small dwellings and shacks. Heavily overpopulated, these patches housed over 45,000 people in 1899, which covered almost a third of the city’s population. According to Jorge, the ‘ilhas’ had turned the city into a graveyard. Plague, an “exotic pestilence”, had implanted itself in a “contagious, immoral and miserable neighbourhood.” (Jorge 1899: 16) To Jorge the conclusion was therefore clear: “It is an epidemic of houses” (Jorge 1899: 16). Only rigorous sanitary measures, as well as the forcible removal of citizens from these deplorable circumstances would contain the epidemic. But the drastic interventions, including compulsory bathing for whole streets, was greeted with strong opposition by the population. The investigating doctors were attacked with stones, cavalry forces had to intervene and control a city that had suffered economic hardship as a result of the strict quarantine (Cohn 2018: 357). Jorge’s program of combined social and hygienic improvement did not succeed. He handed in his resignation in September 1899 and left the city to advance his career in Lisbon.

The Pasteurians, arriving in Porto in August 1899, rejected the simple identification of plague with unhygienic conditions of particularly cramped housing. Rather, Calmette and Salimbeni were investigating the outbreak as a test-case for a specific French approach to bacteriology and epidemiology at the turn of the century. They were interested in the specific configuration of the epidemic as a relationship between bacteria, the environment and the host but considered each of the systems including the pathogen to be a variable factor. Driven by the theory that undergirded the Pasteurians’ production of an immunisation serum, they looked at the epidemic mainly through the conceptual framework of “virulence”(Mendelsohn 2002). The bacterium was not considered a fixed entity but one whose capacity of infection fluctuated in correspondence to external factors, thus explaining the waxing and waning of outbreaks (Amsterdamska 2004). Accordingly, it was important not only to investigate the living conditions of people infected with the bacterium, but also to establish a picture of how the conditions of a European population in its specific environment affected its capacity to ignite an epidemic. “It was necessary,” Calmette wrote, “to determine with exactitude if the microbe was identical with that studied by Yersin in India, and if, following the inception of the virus in the European race, its characteristics had not changed” (Calmette 1900: 108).

Figure 2 HERE

Indeed, the bacteria in Porto was observed to be extremely virulent, and Calmette and Salimbeni witnessed a considerable number of pneumonic cases, which prompted further investigation into the modes of transmission in the city. But their greatest interest was to find out to what extent the serum they had brought would have a beneficial effect and a measurable impact on mortality. The serum was used exclusively in the plague hospital both as an immunization for staff and as a treatment for cases in an early state of the disease. To prove the efficacy of the serum they had to establish a detailed register of all treated cases in the hospital and compare it with all untreated cases in Porto. Many of these cases were never brought to the attention of doctors, as families tended to hide patients and their cases could thus be exploited as a control group. Here, Calmette and Salimbeni could demonstrate the reduced mortality among patients treated with their serum and also that houses and 'ilhas' were not to blame for an increased occurrence of plague. Once they had assembled all cases and their individual characterists and had arranged these cases on a map, the simple conclusion had to be drawn that European populations were just as vulnerable to plague as Indian or Chinese people.

The spatial diagram was the result of a detailed epidemiological assemblage of case studies and their individual characteristics. The paperwork that went into the production of this spatial diagram consists of detailed reconstructions of individual cases, before they were arranged on the map. In Calmette's research papers, we find a stack of individual case reports, each containing a detailed description of the clinical history of the patient, dates of the onset of the plague infection, descriptions of the symptoms and dates of mortality as well as dates of convalescence. Most importantly, Calmette noted the prescription of serum and its effects on the patients. The dates as well as fever curves were plotted onto graphs for each case. These representations of the cases, both descriptions and graphs, were then tied together through the map, were each case appears to be represented through a dot. The resulting sketch of a spatial pattern of the epidemic has then been transformed into the dot-map printed in the Pasteurian's report (Calmette 1900).

Figure 3 HERE

The aesthetic appearance of the spatial diagram printed in the Pasteurians' report is inconspicuous and was at the time used in the visualization of many outbreaks of plague as well as of other diseases. Commonly referred to as dot-maps, originating from the first and most famous one drawn by John Snow for Cholera in 1854 London, the form is built around the incidence of cases (Snow 1855; Koch and Denike 2010). With each dot representing a case, the nominative map produces a visual account of cases to place them on the map to infer spatial and – sometimes- temporal patterns.

In the case of Calmette's map, nothing out of the ordinary is observed. Similar to the diagram of Vetlianka, he separated the outbreak into two periods, one dedicated to cases observed until July 24 1899, and the second for all cases seen until the October 12 of the same year. He could clearly demonstrate that while the dense occurrence of cases in houses and 'ilhas' close to the port might have originally suggested a configuration of plague as a disease of impoverished housing conditions, the second period's distribution across the city – and indeed across social divisions – rendered such framings fully inadequate. Instead, the message of this spatial diagram and its diagrammatic contribution to the discussions around Porto was simply to state that plague seemed to follow the exact same pattern in Europe as it did in comparable outbreaks, and indeed comparable maps of outbreaks in India (Evans forthcoming).

The spatial diagram allowed Calmette to corroborate the characteristic distribution of plague known from previous outbreaks in non-white populations to infer that indeed the first modern occurrence of the disease in a white, European population seem to have no effect on the virulence of the bacteria. Instead, the spatial diagram supported the account of a non-specific spatial distribution of plague in European urban environments.

This conclusion allowed Calmette then to conveniently attribute the comparable harmlessness of the Porto outbreak not to the assumed superiority of the European race, nor to modern hygienic standards, but to the success of the serum therapy and thus to the triumphant intervention of the Pasteurians. The configuration of plague implied was one in which neither houses, nor families, nor individuals were brought into a causal relation, but one in which the focus shifted onto other factors which could explain the spatial and temporal distribution of the disease. Almost in passing, the report of Calmette and Salimbeni concludes that the role of rats, mice and fleas deserved further investigation, as traces of these animals appeared to have a persistent presence around cases. [3]

What the Pasteurians established was a network of relations between the European hosts, the environment of a European port city and the pathogen. The simple dot-map presents here a configuration of three interlocking systems – the host, the environment, the pathogen - each considered to be a variable with the capacity to act on each of the other systems. Plague's visualisation did not infer causality and origin, but sought to establish the patterns and dynamics characteristic of the configuration that the epidemic implies. In Porto, Calmette and Salimbeni used the spatial diagram not to trace the pathogen or to identify its transmission pathways, but to visualize an expectable and repeatable pattern of plague, which had been observed globally. The spatial diagram does emphatically not take on the position of an explanation of the epidemic, it fails to provide further information as to how the specific conditions of Porto or the 'ilhas' might have influenced the spread of the disease. Instead, the diagram appears to be an instrument of exploration and observation, through which the characteristic spatial pattern of plague was identified as configuration and thus effectively universalized.

Conclusion

Epidemics have always resisted definition. But since the mid-nineteenth century, doctors and public health officers have aimed to define the epidemic with the instruments and tools of modern scientific inquiry. The observation of epidemics like plague was often guided by the apparent phenomenon, that the aggregate occurrence of a disease in a population seemed to be structured by different laws and patterns than an individual case of the same disease. But these laws and patterns were notoriously elusive entities and throughout the nineteenth century, epidemiology struggled to earn the badge of a medical science and often failed to arrive at satisfying accounts of the epidemic networks, structures, patterns and rhythms. Nonetheless, the challenge of identifying repeatable, characteristic and recognizable patterns was the principal aim of the early epidemiologist's scholarly work. And spatial diagrams, I have argued here, supported not only these inductive epidemiological investigations. The diagrams also helped to maintain the epidemic as an object of configuration, as a network of systems and as an abstract entity – a series or pattern – that appears within an environment, a population or a combination of both.

In both cases of plague, the spatial diagrams were developed not to support theories of causality or to argue about attributable origins of the disease, but to advance a thinking of epidemics beyond mono-causal and deductive explanations. Neither the always-suspicious sanitary states, nor the overwhelming attraction of bacteriological agency were privileged in the accounts of Minkh and Calmette and Salimbeni. But both, the Ukrainian doctor as well as the Pasteurians rejected simplified and popular explanations and instead proposed with their spatial diagram a way of seeing that pointed beyond dated sanitary anxiety and resisted the allurement of the modern laboratory. Their work on the outbreaks in Vetlianka and Porto insisted instead on the value of epidemics as unique configurations of a set of circumstances. Their tradition of epidemiological reasoning was committed to the exposure of the relations, the systems and the networks between humans, animals, the material environment, climatic seasonality, historical conditions and pathogens.

Diagrams enabled an epidemiological practice grounded in technologies of observation and conceptual combination, bringing topographies of a disease to bear on environmental and social characteristics of places. Through diagrams, epidemiologists were able to combine spatial and temporal dimensions, include hygienic considerations, develop aspects of population density and susceptibility, integrate notions of variable virulence and express a notion of the epidemic as a configuration. In spatial diagrams, epidemiologists could render the epidemic as a conceptual entity: an object of research, which had accrued value for epidemiologists without needing to be an instrument that clarified causality, nor serving as a blueprint for strategies of containment.

The aim of this article has been to reinvigorate a sense of the historical contingency of epidemiological reasoning and to showcase epidemiology's spatial diagram as an instrument of inductive reasoning with a broad range of disciplinary and theoretical capacity. In the spatial diagrams we find traces of the radical epistemological indeterminacy, which characterizes many of the endeavors of making an epidemiological science. I leave it to following research to trace the residues of this tradition in the epidemiological visualizations of today's global health and digital medicine. But epidemics like plague continue to resist being known as well-defined objects of inquiry and their occurrence still poses serious challenges to the discipline that aims to master their observation, analysis and representation (Kosoy and Kosoy 2017). Clearly, this article has not aimed to deliver another, more comprehensive definition, nor did it seek to remove the conceptual precariousness of epidemiology's object of research. Rather, I have argued that the status of the epidemic as a scientific object with blurred boundaries and contested ontologies required the representational capacities of the spatial diagram. They framed and suspended the concept of an epidemic in an open-ended way which had perhaps no other purpose than to grasp the multi-layered, unusual and inconclusive formation of the epidemic.

Notes

1 These are probably not accurate case numbers as the city's mortality reports see a 20 percent increase for 1899 in Porto suggesting at least another few hundred cases (Almeida 2013).

2 The serum was made similarly to other vaccines developed in the Institut Pasteur by culturing attenuated bacteria in horses. The serum had only limited efficiency and its capacity to immunize was and remained highly contested.

3 At that time the animal vector of plague was still a subject to speculation, but many were intrigued by the pivotal role of animal vectors in the distribution of the disease adding yet another layer to the complex configuration of plague.

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